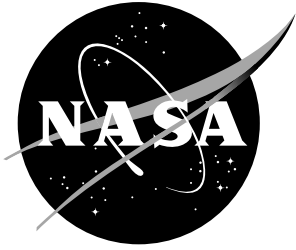


Random Vibration and Torque Tests of Fasteners Secured With Cable, Room Temperature Vulcanized (RTV) Rubber, and Closed Cell Foam to Support the Launch of STS-82

V.H. Yost



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V.H. Yost
Marshall Space Flight Center • MSFC, Alabama

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TECHNICAL MEMORANDUM

RANDOM VIBRATION AND TORQUE TESTS OF FASTENERS SECURED WITH LOCKING CABLE, ROOM TEMPERATURE VULCANIZED (RTV) RUBBER, AND CLOSED CELL FOAM TO SUPPORT THE LAUNCH OF STS-82

I. INTRODUCTION

Before every flight of the Space Transportation System (STS), technicians at the Kennedy Space Center (KSC) inspect the system. This inspection is called a walkdown. During a walkdown of the orbiter for STS-82, technicians found several safety cables for bolts with missing or loose ferrules. Typically, two or three bolts are secured with a cable which passes through one of the holes in the head of each bolt and a ferrule is crimped on each end of the cable to prevent it from coming out of the holes. The purpose of the cable is to prevent bolts from rotating should they become untightened. Two joints where the Space Shuttle main engine (SSME) is bolted to the orbiter are where missing and loose ferrules were found. These joints are F1, low pressure fuel pump, and F4.3, fuel bleed line. These discrepancies were recorded at KSC on an Inspection Discrepancy and Correction Record form. However, there are a number of other bolts on the orbiter that are secured with lock wire or cable with ferrules, then the bolt head and wire or cable are covered with room temperature vulcanized (RTV) rubber which is allowed to cure before they are covered with foam insulation. These bolts and lock wires or cables with ferrules cannot be inspected without removing the foam.

The Associate Director, Technical, at the Marshall Space Flight Center (MSFC), directed that tests be made at MSFC to determine whether bolts with locking cables with no ferrules which are covered with RTV rubber and foam will untighten when subjected to the same random vibration as the SSME. The test fixtures and tests were made between February 3 and 10, 1997, at MSFC. The participants and their contributions are listed in appendix A.

II. DESCRIPTION

A. Random Vibration Tests

1. Fixture, Equipment, and Supplies

- Vibration test fixture.
- Molykote, G–N paste, Dow Corning Corporation, Midland, MI.
- Cable, 3 strands \times 7 wires, 0.006-inch diameter per strand and a nominal diameter for the cable of 0.035 inch.
- Room temperature vulcanized rubber, a.k.a. Silicone Elastomer, MIL–A–46106B, Accumetric, Inc., Elizabethtown, KY 42701.
- Epoxi-Patch kit, Hysol 608, NSN 8040–00539–7798, The Dexter Corporation, Seabrook, NH 03874–4018.
- Great Stuff Minimal Expanding Foam Sealant, Insta-Foam Products, Inc., A Division of Flexible Products Co., Joliet, IL 60435–3187.
- Master heat gun, 300/500 °F, Model HG–301A, Master Appliance Corp., Racine, WI 53403.
- Proheat VAR (temp. heat gun), 1,500 W, model PH 1200, Master Appliance Corp., Racine, WI 53403.
- Torque wrench, 0–600 inch-pounds, Snap-On Tools Corp., Kenosha, WI (calibration identification number N028262, calibrated 9/12/96, due 3/12/97).
- Torque wrench, 0–75 inch-pounds, Snap-On Tools Corp., Kenosha, WI (calibration identification number M631281, calibrated 11/5/96, due 5/5/97).
- Vibration machine, KI number K4523, Kimball Industries, Inc., Monrovia, CA.

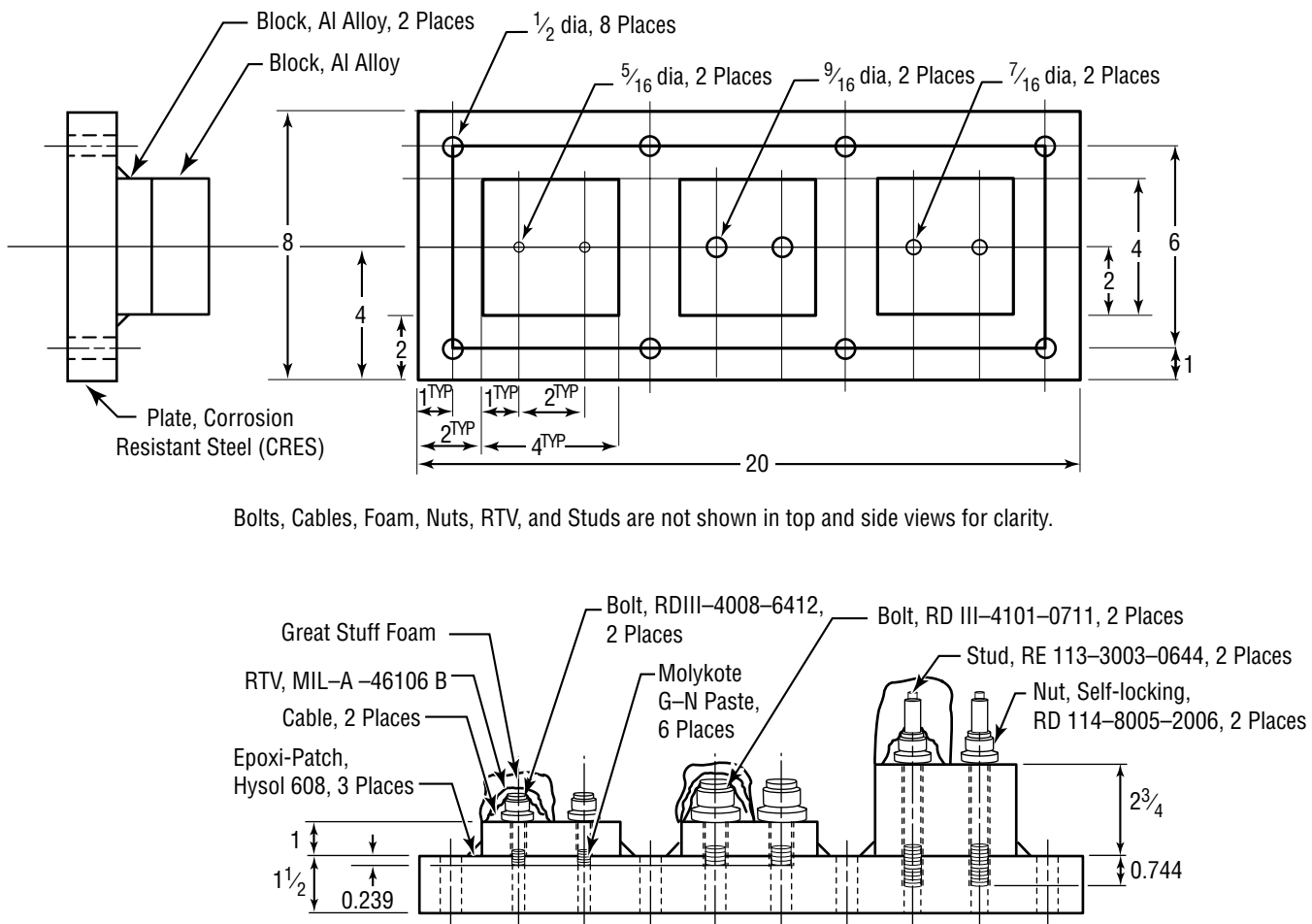
2. Documents

- Bolt, spline drive, reduced shank, short thread, ultrasonic length, alloy 718, 220 ksi, Rockwell International Corp., drawing number RD 111–4101.
- Applied room temperature cured silicone sealing compound, Rockwell International Corp., specification number MA01106–303, figure 2 and installation—SSME interface, drawing number V0410801, view H and sections F–F and G–G.
- SSME Structural Design Criteria, BNA Rocketdyne Division RSS–8561–25, May 23, 1996, SSME Vibration Criteria, Zone D, pages 4–56.
- Standard, threaded fasteners, torque limits for, MSFC–STD–486A, December 11, 1987.

3. Test Setup

Figure 1 shows the vibration test fixture (VTF). Prior to the first vibration test, the test conductor learned that the holes in the aluminum (Al) block were larger than they should be for aerospace specifications—0.312-inch diameter for the 0.250-inch diameter bolts, 0.500-inch diameter for the 0.4375-inch diameter bolts, and 0.4375-inch diameter for the 0.375-inch diameter studs. For aerospace application, through holes for bolts and studs are only a few thousandths of an inch larger than the bolt or stud. To prevent the blocks from sliding laterally during the vibration tests, the test conductor directed that a bead of Epoxi-Patch be placed around the perimeter of each block at the joint between the block and plate. Curing was accelerated with two heat guns.

A comparison of the block height and each bolt and stud showed the thread engagement in the plate to be only 0.239 inch for the bolts. It should have been at least 1.5 times the diameter of the bolts, which is 0.375 inch for the 0.250-inch bolt and 0.656 inch for the 0.4375-inch bolt. The 0.375-inch diameter studs had a thread engagement of 0.744 inch, which is 0.181 inch more than is required. The threads of each bolt and stud were coated with Molykote G-N paste before installation.



Note: All dimensions are inches.

FIGURE 1.—Vibration test fixture (VTF).

Figure 2 shows the VTF bolted to the vibration machine table and the accelerometer used to measure the vibration to which the VTF was subjected. It also shows the bolts which were secured by cable, RTV, and Great Stuff Expanding Foam and those that were not, as well as the stud that was secured by RTV and foam and the stud that was not.

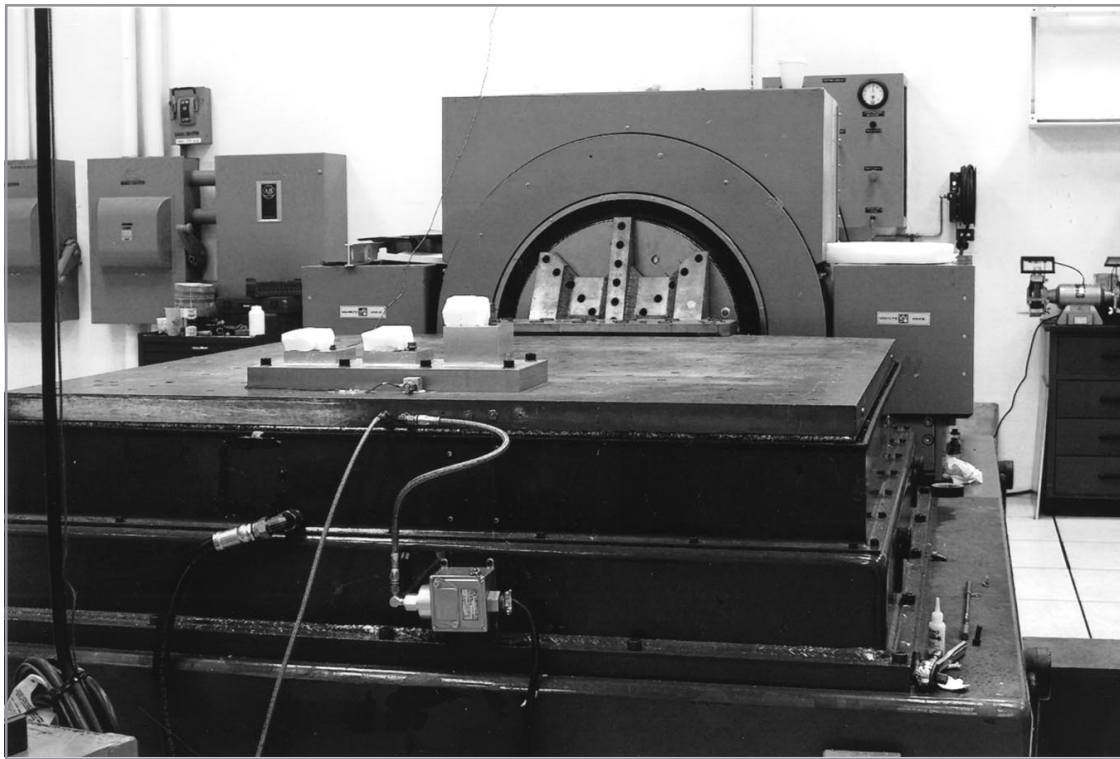


FIGURE 2.—Vibration machine with VTF.

4. Discussion

The purpose of the vibration tests was to determine whether bolts and studs tightened to various degrees—both secured and not secured with various combinations of cable, RTV, and foam—will loosen when subjected to one of the several SSME random vibration criteria.

For the first vibration test (run 1), all bolts and studs were finger-tight. The random vibration requested was for the SSME Vibration Criteria, Zone D (see appendix B). Prior to this test, these random vibrations caused an electrical fusible link in another vibration machine to fail. So, for this test, the vibration machine shown in figure 2 was run at -3 dB below the levels shown in appendix B (44.94 grms versus 63.48 grms). After 31 seconds at this level, the unsecured 0.250-inch bolt rotated counterclockwise (loosened) 80 degrees, and the 0.4375-inch bolt and 0.375-inch bolt loosened 60 degrees. The data recorded for this and all other vibration tests are in appendix C. Figure 3 shows the VTF and loosened bolts after run 1. Figures 4 and 5 show the loosening of 0.250-inch bolt and 0.375-inch stud at 80 and 60 degrees, respectively.



FIGURE 3.—VTF and loosened fasteners after run 1.



FIGURE 4.—VTF with loosened 0.250-inch bolt after run 1.

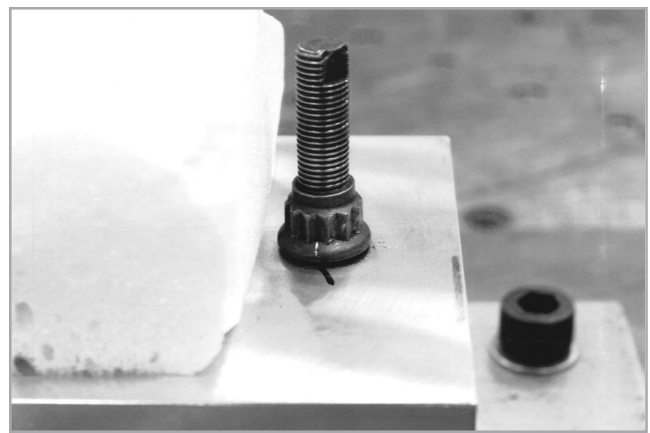


FIGURE 5.—VTF with loosened 0.375-inch stud after run 1.

For run 2, the bolts were left in the loosened positions at the end of run 1. They were then subjected to 48 seconds of the random vibration described in appendix B and presented graphically in appendix D, figure D-1. The unsecured 0.250- and 0.4375-inch bolts loosened an additional 10 and 740 degrees, respectively, and the 0.375-inch stud loosened an additional 210 degrees. Figure 6 shows the 0.4375-inch bolt loosened 800 degrees, 60 degrees from run 1 and 740 degrees from run 2.

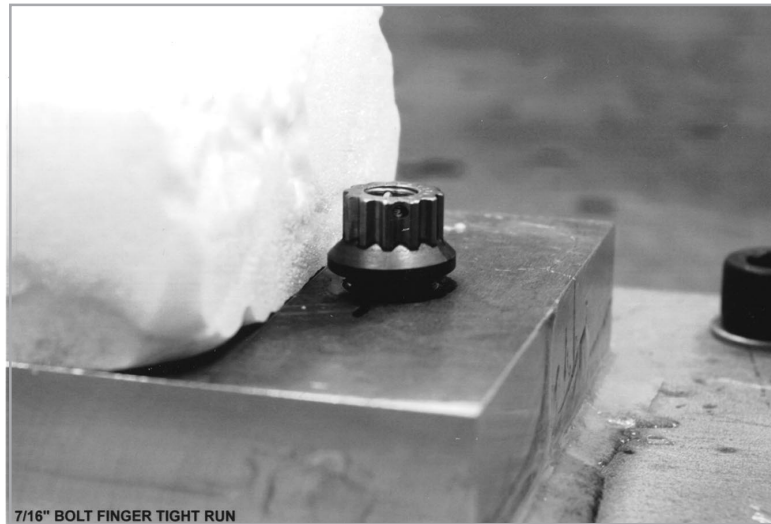


FIGURE 6.—VTF with loosened 0.4375-inch bolt after run 2.

Prior to run 3, the 0.250- and 0.4375-inch bolts were tightened to 45 and 420 inch-pounds, respectively, and the 0.375-inch stud to 150-inch pounds. These torques were obtained from MSFC-STD-486A. For run 3, the bolts and stud were subjected to 182 seconds of the random vibration criteria described in appendix B and presented graphically in appendix D, figures D-2 through D-6. Run 3 was made in five parts because the vibration machine was operating at essentially its maximum random composite reference level, and it electrically turned itself off at 42, 58, 104, 147, and 182 seconds. At 143 seconds, the 0.375-inch stud loosened (see fig. 7). Figure 8 shows the VTF, tight 0.250- and 0.4375-inch bolts, and a loosened stud. During the early part of this run, the bond between the plate and the Epoxi-Patch broke on the four sides of the three blocks.

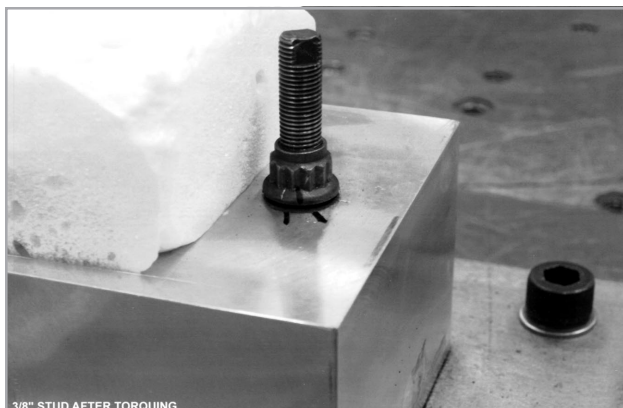


FIGURE 7.—VTF with loosened 0.375-inch stud after run 3.

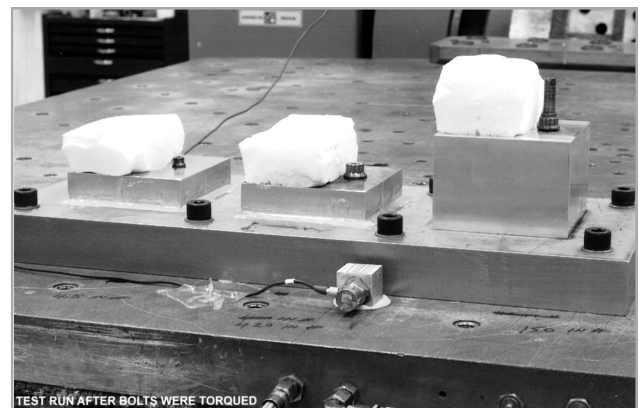


FIGURE 8.—VTF with loosened fasteners after run 3.

For run 4, the bolts and stud were subjected to 39 seconds of the random vibration described in appendix B and presented graphically in appendix D, figure D-7. During this test, the test conductor placed his finger on the top of the loosened stud to determine by touch if much torque was required to prevent the stud from loosening more. The torque was estimated to be only a few inch-pounds. The 0.250- and 0.4375-inch bolts did not loosen during run 4.

After run 4, the foam was removed from the two bolts and one stud (see fig. 9). The 0.250- and 0.4375-inch bolts under the foam were secured with a 2-inch-long cable and RTV over the cables, bolt heads, and onto the VTF. The RTV was found to be only partially cured because the foam was sprayed over it immediately following the application of the RTV. This inhibited the RTV's absorption of moisture from the air which RTV needs to cure. Inspection of the bolts and stud, which were only finger-tight, showed they had not loosened. Figures 10, 11, and 12 show the bolts and stud with the RTV removed. The marks on the bolt heads, stud nut, and VTF were aligned after the four runs, a total of 300 seconds of random vibration.

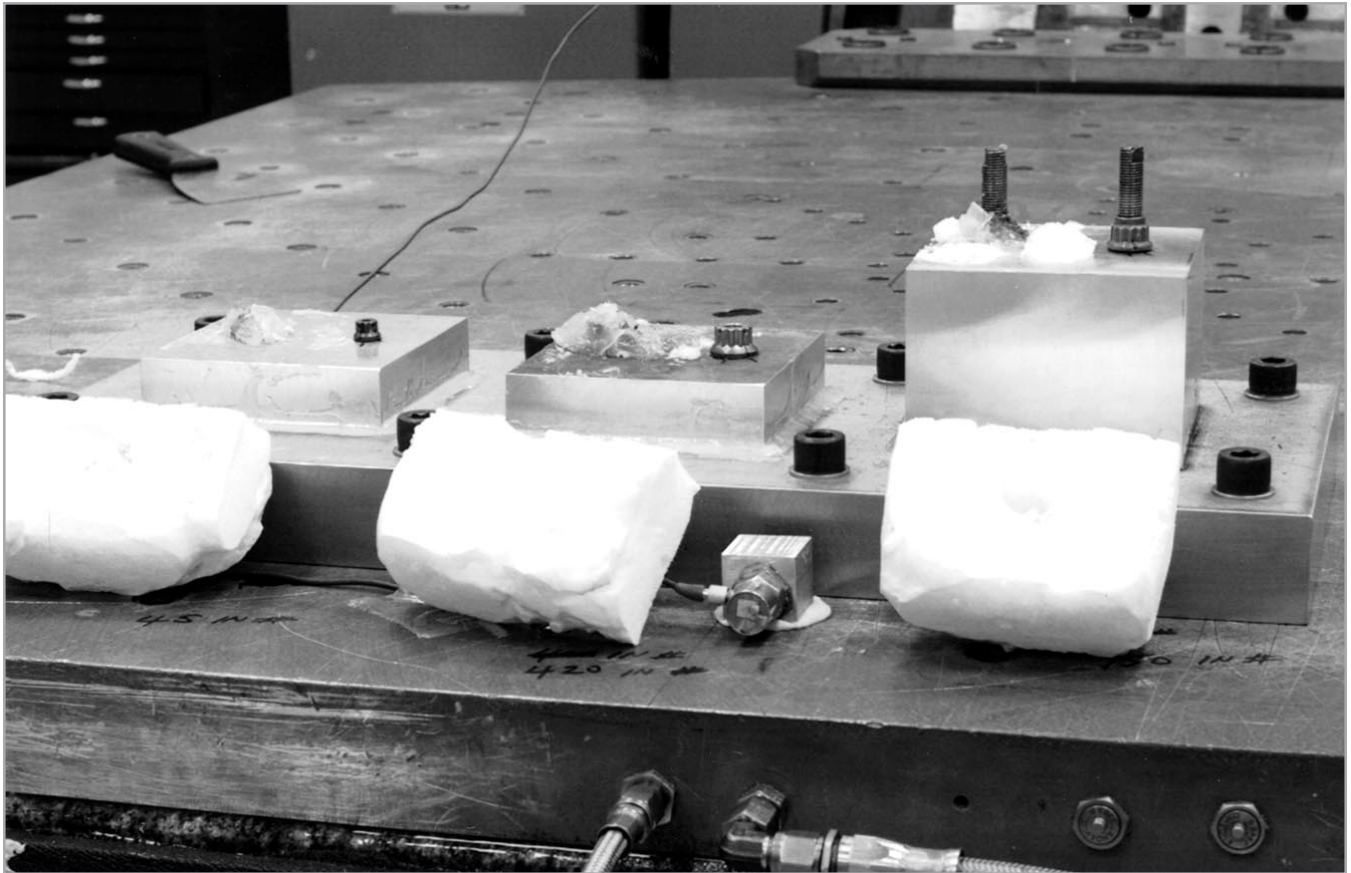


FIGURE 9.—VTF with foam removed after run 4.

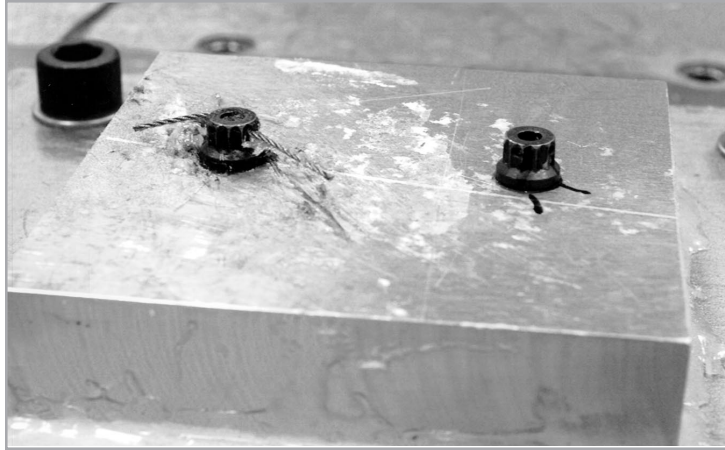


FIGURE 10.—The 0.250-inch bolt with cable, and RTV and foam removed after run 4.

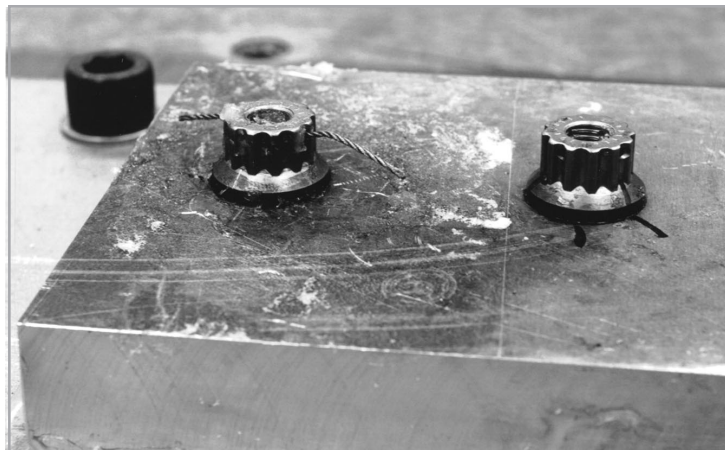


FIGURE 11.—The 0.4375-inch bolt with cable, and RTV and foam removed after run 4.

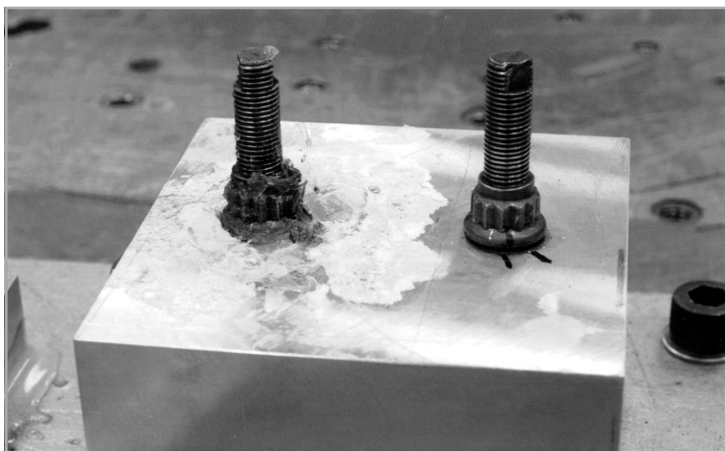


FIGURE 12.—The 0.375-inch stud with RTV and foam removed after run 4.

B. Torque Tests

1. Fixture, Equipment, and Supplies

- Torque test fixture.
- Bolt, external wrench, A-286, 20,000 psi, Rockwell International Corp., standard RD 111-4008 and 111-4009
- Bolt, locking cable, 3 strands \times 7 wires, 0.006-inch diameter per strand and a nominal diameter for the cable of 0.035 inch
- Great Stuff Minimal Expanding Foam Sealant, Insta-Foam Products, Inc., a division of Flexible Products Co., Joliet, IL 60435-3187.
- Nut, check, AN 316-4, 316-5, and 316-6.
- Torque wrench, 0-30 inch-pounds, Snap-On Tools Corp., Kenosha, WI (calibration identification number M26844, calibrated 8/15/96, due 2/15/97).

2. Documents

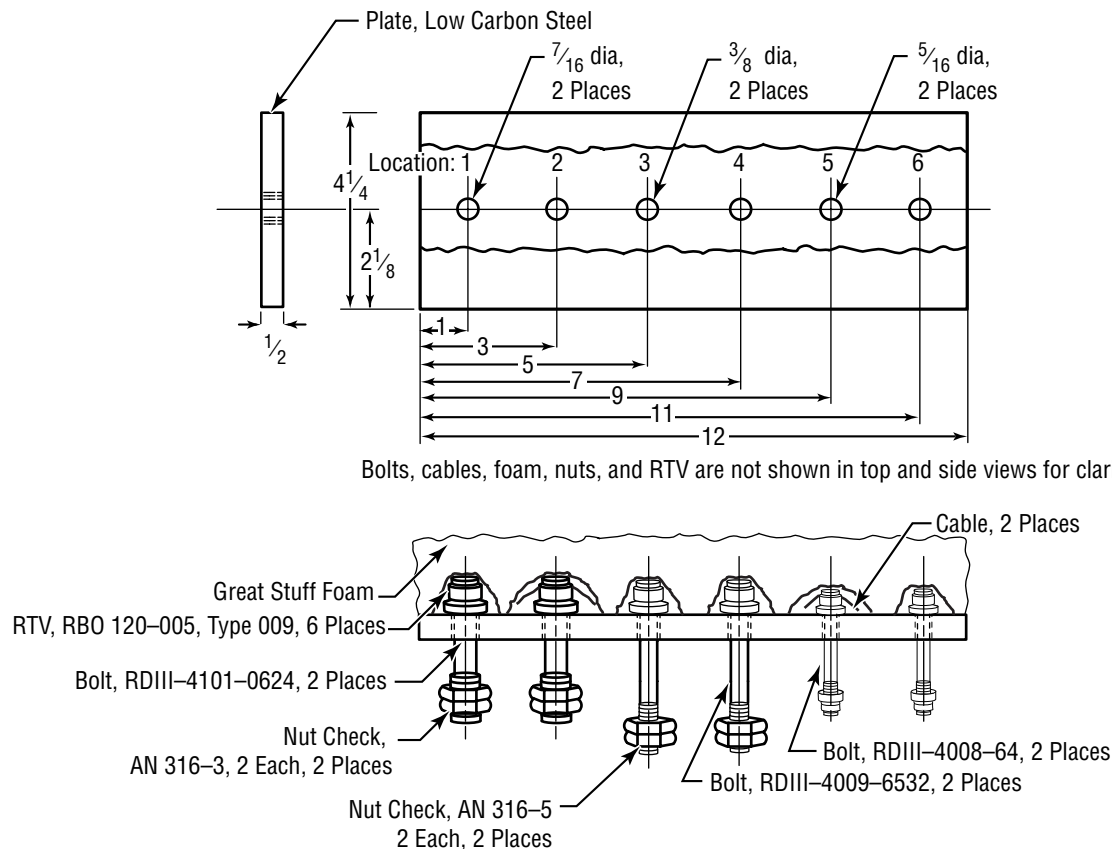
Applied room temperature cured silicone sealing compound, Rockwell International Corp., specification number MA0106-303, figure 2 and installation—SSME interface, drawing number V0410801, view H and sections F-F and G-G

3. Test Setup

Figure 13 is an illustration of the torque test fixture (TTF) and the combination of cable, RTV, and foam for each bolt. The bolts at locations 1, 3, 4, and 6 did not have cables, so only RTV and foam were used to secure them.

The holes in the plate were larger than they should be for aerospace applications. Holes 1 and 2 were 0.4375-inch diameter for the 0.375-inch diameter bolts, holes 3 and 4 were 0.375-inch diameter for the 0.3125-inch diameter bolts, and holes 5 and 6 were 0.3125-inch diameter for the 0.250-inch diameter bolts.

The bolts were mounted in the plate and one cable, approximately 2 inches long, was threaded through a hole in the head of bolts 2 and 5. Then the bolt heads and cables were covered with RTV as described in appendix E. Next, RTV was cured in air for 6 hours. Finally, the bolt heads, cables, and RTV were covered with Great Stuff Foam, which was cured for 16 hours. Prior to the torque tests, the plate was laid foam-down on a bench so the torque wrench with the appropriate socket could be placed on the double nuts with the wrench dial facing up.



Bolts, cables, foam, nuts, and RTV are not shown in top and side views for clarity.

FIGURE 13.—Torque test fixture (TTF).

4. Discussion

There were two purposes for the torque test. The first was to determine the torque required to break the bond between bolts, secured by combinations of cable, RTV, and foam, and the plate in which the bolts were mounted in through holes. The second was to determine the torque required to rotate the bolts in the holes once the bond was broken. The torque test made on each bolt consisted of two parts. First, the torque required to break the aforementioned bond between the plate and bolt was reached, and the break torque was measured. Second, the torque required to rotate each bolt after the bond was broken, the run torque, was measured. The data for these tests are in appendix F.

For the 0.375-inch diameter bolts, the break torque was 0.5 inch-pounds greater for bolt 2, which had the cable through its head, than for bolt 1 (7 versus 6.5 inch-pounds). However, once the bond with the plate was broken for these bolts, bolt 1, which did not have the cable, had the greater run torque (3 versus 2 inch-pounds). Bolts 3 and 4 are 0.3125-inch diameter and did not have cables, only RTV and foam. Like the 0.375-inch diameter bolts, the break torques were within 0.5 inch-pounds of each other (bolt 3, 4 inch-pounds, and bolt 4, 3.5 inch-pounds). The run torques were also within 0.5 inch-pound of each other. Bolt 3 had the lower torque (bolt 3, 1.5 inch-pounds, and bolt 4, 2.0 inch-pounds).

For the 0.250-inch diameter bolts, bolt 5—which was secured with a cable, RTV, and foam—had nearly twice the break torque as bolt 6, which was secured RTV and foam (bolt 5, 3.5 inch-pounds and bolt 6, 2 inch-pounds). Both bolts had a run torque about one-half the break torque (1.5 inch-pounds).

III. CONCLUSIONS

A. Random Vibration Tests

1. Bolts which were finger-tight, had anti-seize compound on their threads, had less than the required thread engagement, and were secured with cable, RTV, and foam did not loosen when subjected to one of the many SSME random vibration criteria (SSME random vibration).
2. The stud, which was finger-tight and had anti-seize compound on its threads and was secured with RTV and foam, did not loosen when subjected to SSME random vibration.
3. Bolts and studs which were finger-tight, had anti-seize compound on their threads, and were not secured with cable, RTV, or foam, loosened when subjected to SSME random vibration.
4. Bolts which were tightened to the specified torque, had anti-seize compound on their threads, had less than the required thread engagement, and were not secured with cable, RTV, or foam did not loosen when subjected to SSME random vibration.
5. The stud which was tightened to the specified torque, had anti-seize compound on its threads, had about 2 times the required thread engagement and was *not* secured with cable, RTV and foam loosened when subjected to SSME random vibration.

B. Torque Tests

6. Bolts in through holes in a plate and secured with cable, RTV, and foam require 7 to 75 percent more torque to break the just-described securing system than bolts secured with only RTV and foam.
7. For bolts in through holes in a plate, whether they were secured with cable, RTV, and foam, or RTV and foam, had running torques of 28 to 75 percent of the break torque.
8. For bolts secured with RTV and foam, both the break and running torques increased as bolt diameter increased.
9. For bolts secured with cable, RTV, and foam, both the break and running torques increased as bolt diameter increased.

C. General

10. Holding the loose stud with one finger on top of the stud when subjecting the stud to SSME random vibration tended to show that small torques required to break the RTV and foam securing system would be more than sufficient to prevent the stud from loosening.

IV. RECOMMENDATION

Based on the results of these tests, it was recommended that the RTV and foam covering bolts and studs not be removed on STS-82 for the purpose of determining whether the cables have missing or loose ferrules.

APPENDIX A— CONTRIBUTORS

The following participants, listed in alphabetical order, contributed the items which follow their names:

Vincent P. Bendel	Manufactured the vibration and torque test fixtures.
Steve R. Brewster	Vibration table hole pattern for vibration test fixture design; Lead Engineer, Dynamics Test Branch and signator of a Letter Report titled SSME Bolt Vibration Development Test, SSME–DEV–ED97–017, February 13, 1997.
Melvin A. Bryant III	Test procedure and test conductor for the vibration tests.
Vincent P. Caruso	Provided bolt, bolt torque, foam, and RTV specifications and vibration test support.
Archie D. Coleman	Chief, Dynamic Test Branch; approving authority for a Letter Report titled SSME Bolt Vibration Development Test, SSME–DEV–ED97–017, February 13, 1997; grantor of permission to use the graphs in appendix D.
Louis M. Cranford III	Assembled the torque test fixture.
Ronald L. Daniel, Jr.	Identified flight materials and found similar items.
Danny R. Duke	Made the torque tests.
Thomas W. Hartline	Prepared inspection discrepancy and correction reports.
Rolf D. Hofmann	Engineering technician for the vibration tests and signator of a Letter Report titled SSME Bolt Vibration Development Test, SSME–DEV–ED97–017, February 13, 1997.
Robert M. Lightfoot	Provided Test Preparation Sheet for the torque test.
James P. McGee	Vibration test engineer.
Chip Moore	Advice on threaded fasteners and the effect of putting molybdenum disulfide on their threads.
Gail L. Richey	Obtained Great Stuff Foam from MSFC's Central Substore and typeset the report.

Robert J. Schwinghamer	Associate Director, Technical, MSFC, made the request.
Rocky S. Stephens	Vibration test engineer; vibration machine operator; provided bolt torque specification; author of a Letter Report titled SSME Bolt Vibration Development Test, SSME-DEV-ED97-017, February 13, 1997; and grantor of permission to use the graphs in appendix D.
Ronald E. Tepool	Vibration test fixture design concept and test conductor for the torque tests.
Charles D. Thigpen	System Management and Quality Assurance for the torque tests.
John T. Towry	Vibration test fixture design concept, and engineering sketches of the vibration and torque test fixtures.
Larry Salter	Application of RTV on bolt head drawings and specifications.
Vaughn H. Yost	Concept for torque test fixture, locking cable, vibration specification, vibration test data recorder, and technical memorandum author.

**APPENDIX B—
SSME VIBRATION CRITERIA, ZONE D**

Radial From Engine Centerline (Engine Y–Z Plane)

Steady-State Random Vibration Amplitudes–R5:

20 to 110 Hz	@ 0.02(grms) ² /Hz
160 to 240 Hz	@ 1.0 (grms) ² /Hz
250 to 270 Hz	@ 4.0 (grms) ² /Hz
280 to 300 Hz	@ 0.90(grms) ² /Hz
310 to 350 Hz	@ 5.0 (grms) ² /Hz
360 to 380 Hz	@ 3.0 (grms) ² /Hz
400 to 510 Hz	@ 4.0 (grms) ² /Hz
530 to 630 Hz	@ 3.0 (grms) ² /Hz
680 to 710 Hz	@ 1.0 (grms) ² /Hz
720 to 750 Hz	@ 1.8 (grms) ² /Hz
800 to 830 Hz	@ 0.8 (grms) ² /Hz
860 to 950 Hz	@ 1.0 (grms) ² /Hz
980 to 1,200 Hz	@ 3.0 (grms) ² /Hz
1,220 to 1,310 Hz	@ 4.0 (grms) ² /Hz
1,830 to 2,000 Hz	@ 0.7 (grms) ² /Hz

Random composite reference level = 63.48 grms

**APPENDIX C—
RANDOM VIBRATION TEST DATA**

Run	Z-Axis	Bolt Diameters			Power Level	Time (Sec)
		0.250 in	0.4125 in	0.375 in		
1	Exposed bolts unloosened	80 deg	60 deg	60 deg	−3 dB	31
2	Exposed bolts unloosened further	10 deg	740 deg	210 deg	Full Power	48
3	Exposed bolts tightened to:	45 in-lb Remained tight	420 in-lb Remained tight	150 in-lb Came loose at 143 sec	Full Power	182
	Covered bolts (foam)	Lock cable in partially cured RTV prevented rotation of bolt	Lock cable in partially cured RTV prevented rotation of bolt	No lock cable, locking nut on stud did rotate, stud was loose in CRES plate but did not rotate, 0.003 inch feeler gauge will go between block and CRES plate but 0.004 inch will not		261
4	Holding stud by placing index finger on top of stud showed very little torque is required to prevent rotation				Full Power	39

**APPENDIX D—
GRAPHS: RANDOM VIBRATION VERSUS TIME**

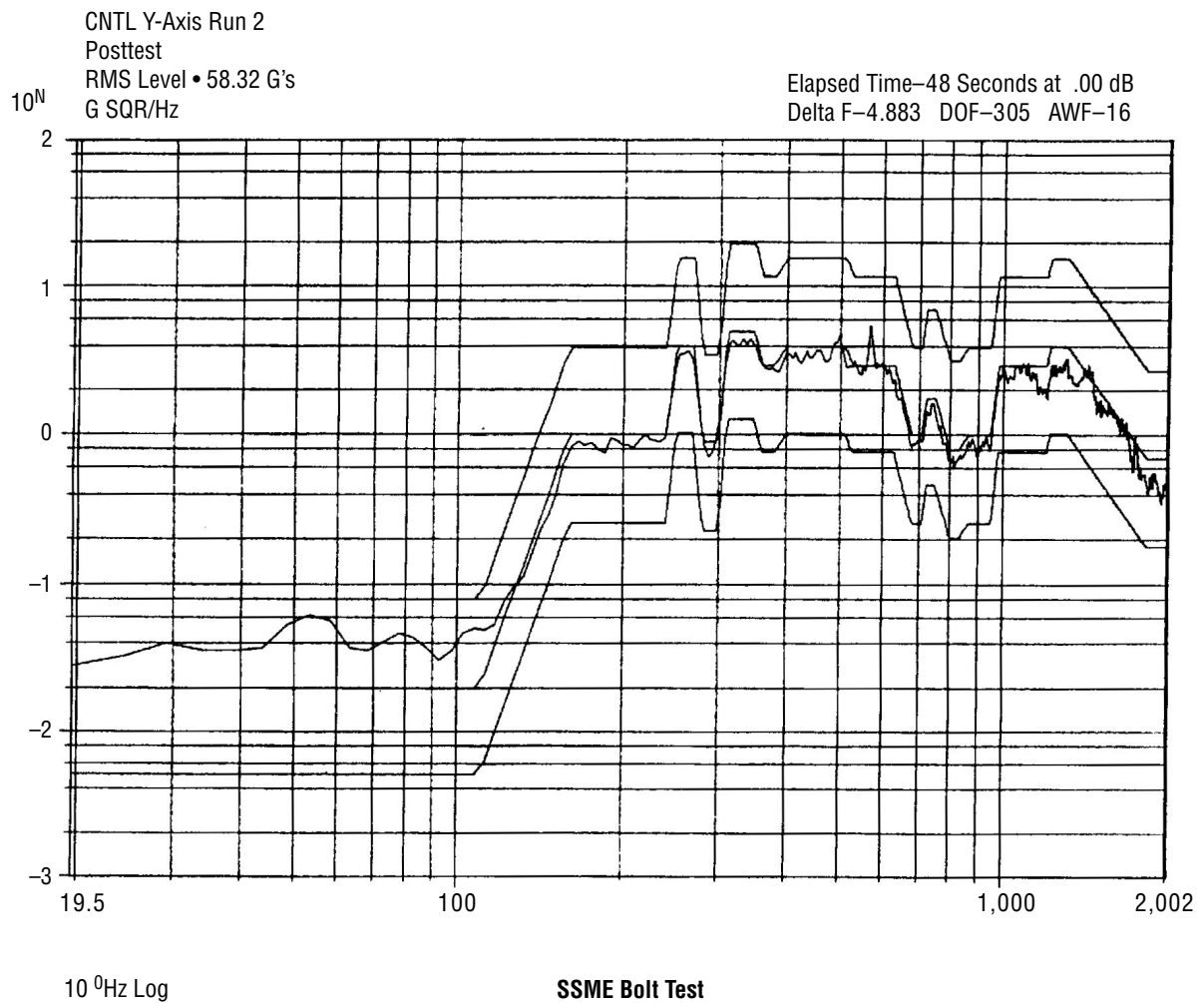


FIGURE D-1.—Run 2, at 48 seconds.

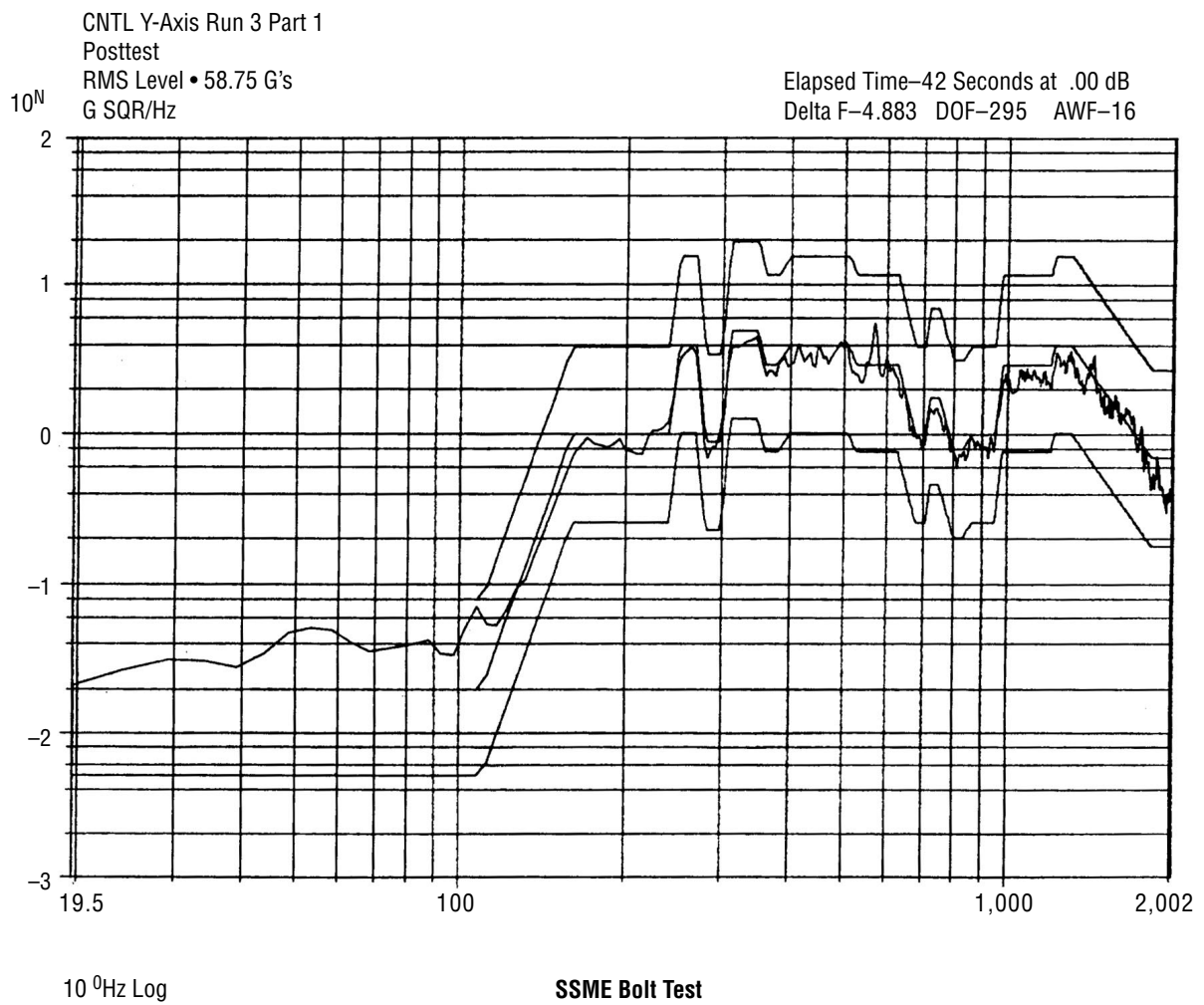


FIGURE D-2.—Run 3, part 1, at 42 seconds.

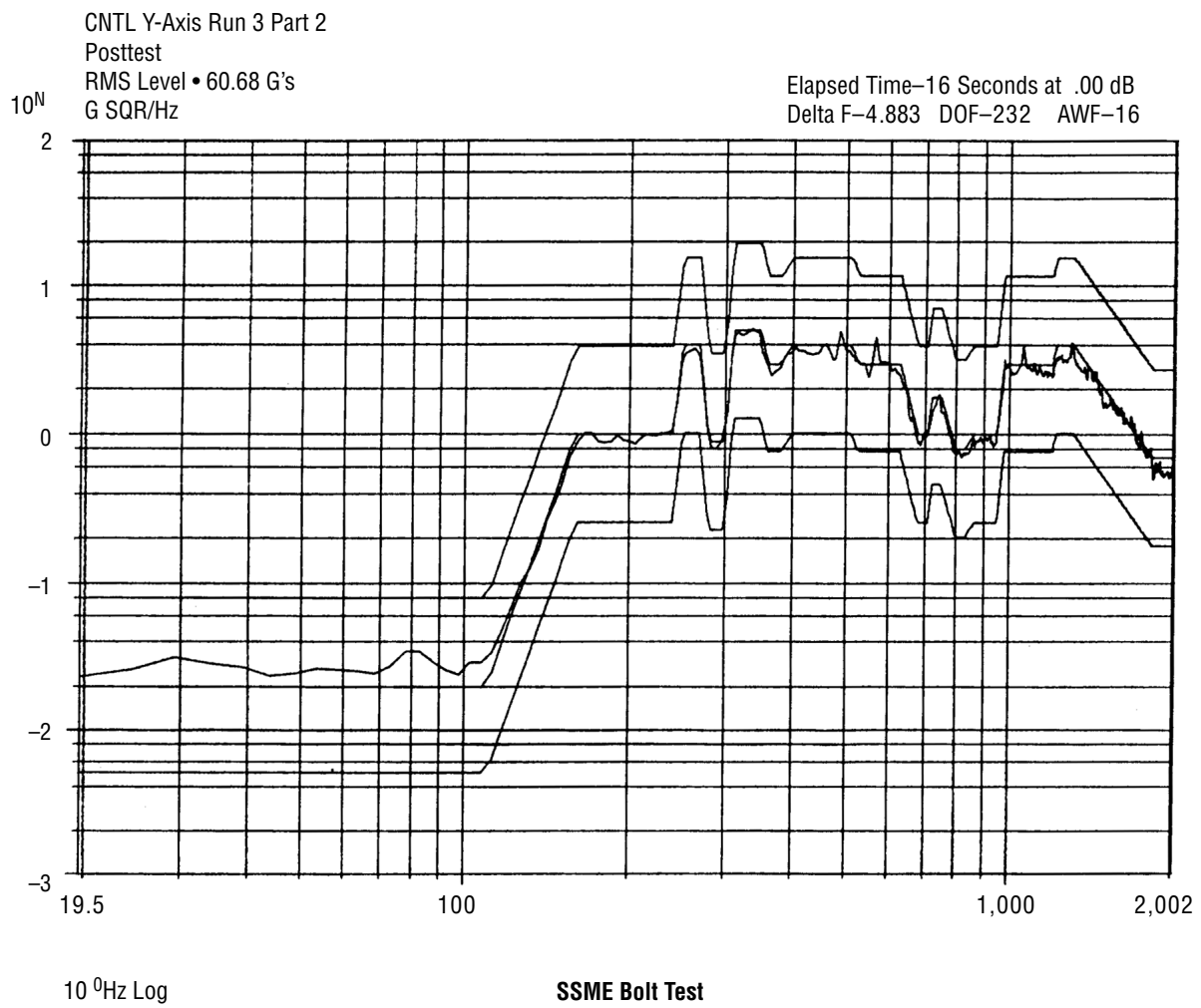


FIGURE D-3.—Run 3, part 2, at 16 seconds.

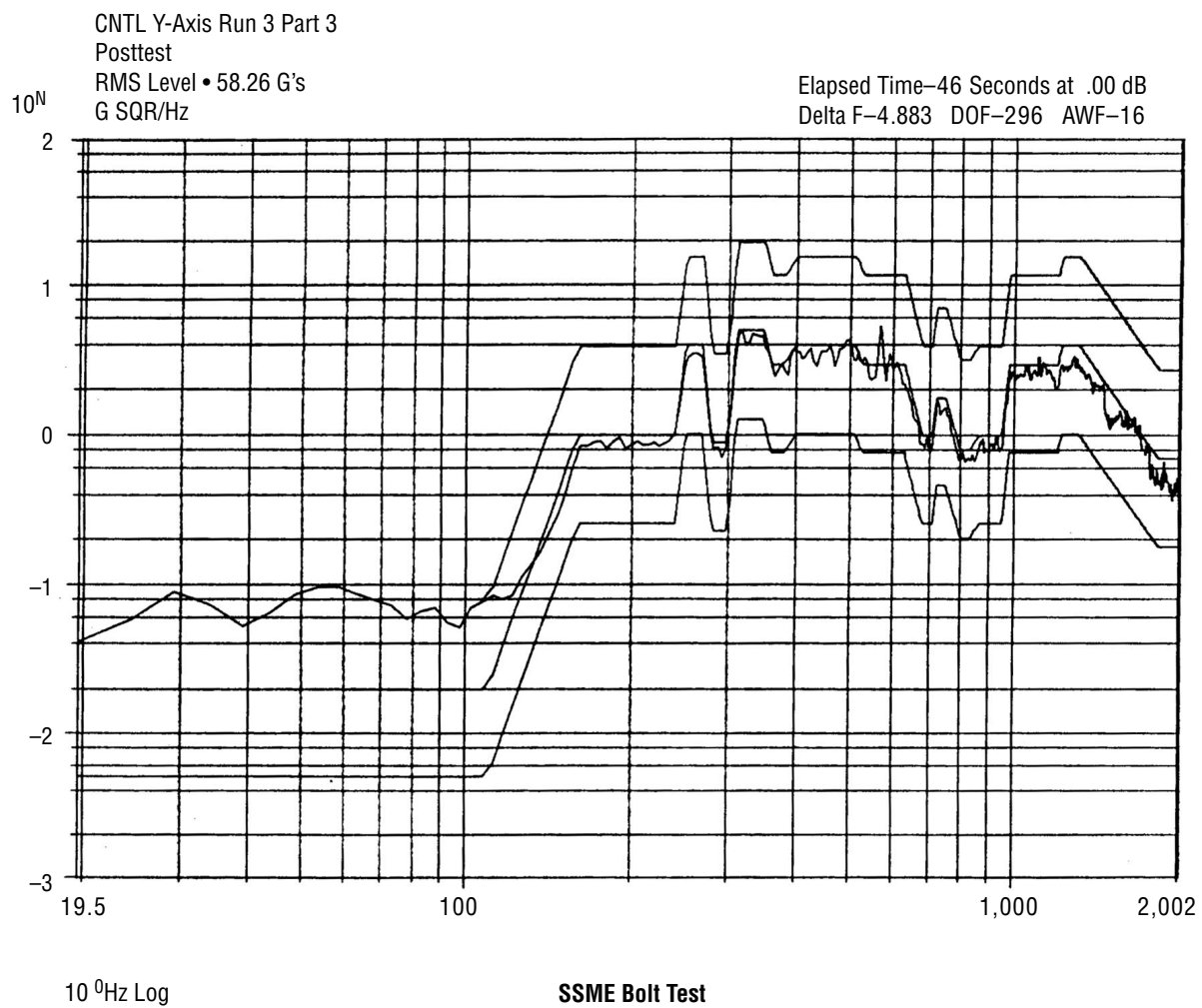


FIGURE D-4.—Run 3, part 3, at 46 seconds.

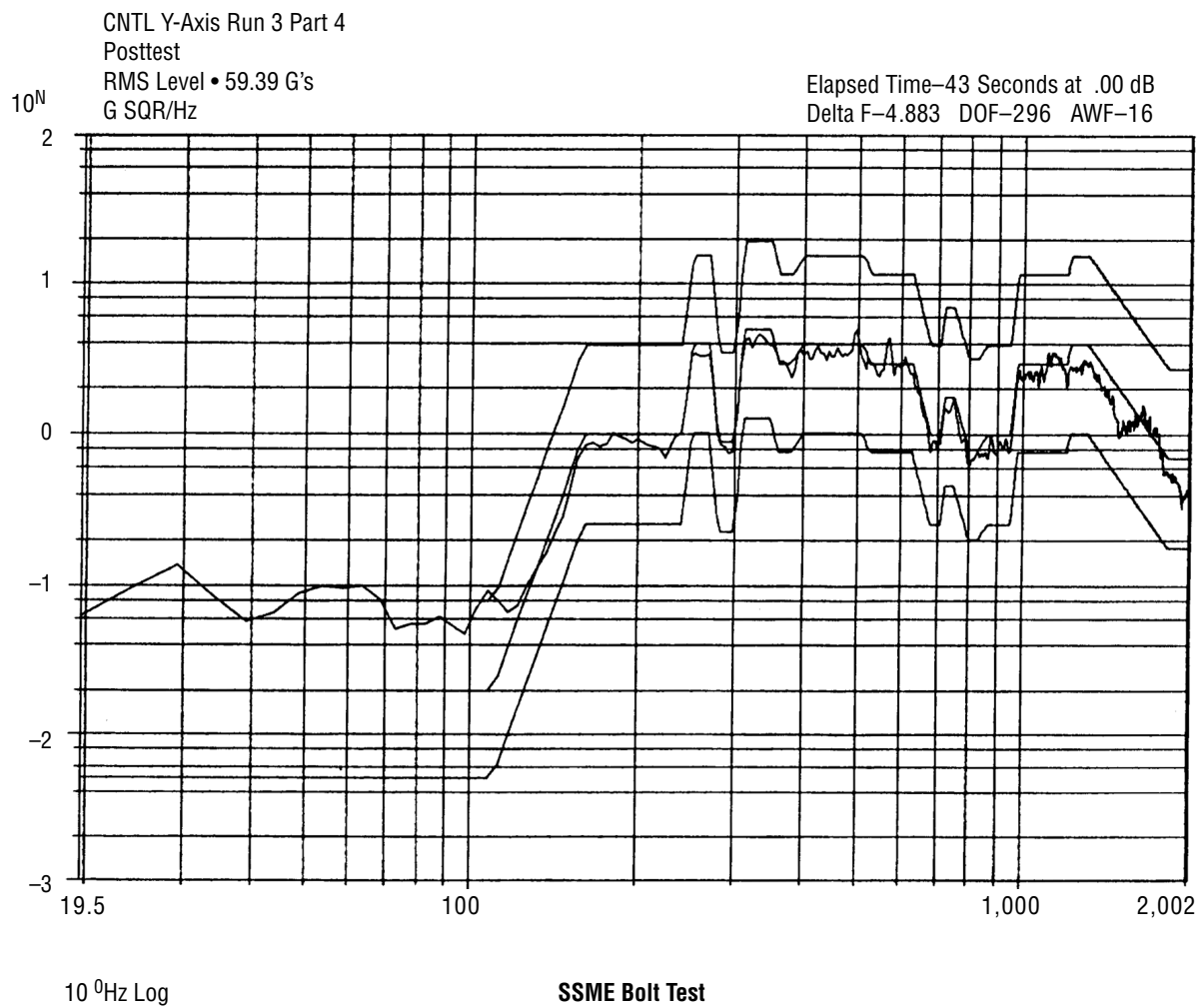


FIGURE D-5.—Run 3, part 4, at 43 seconds.

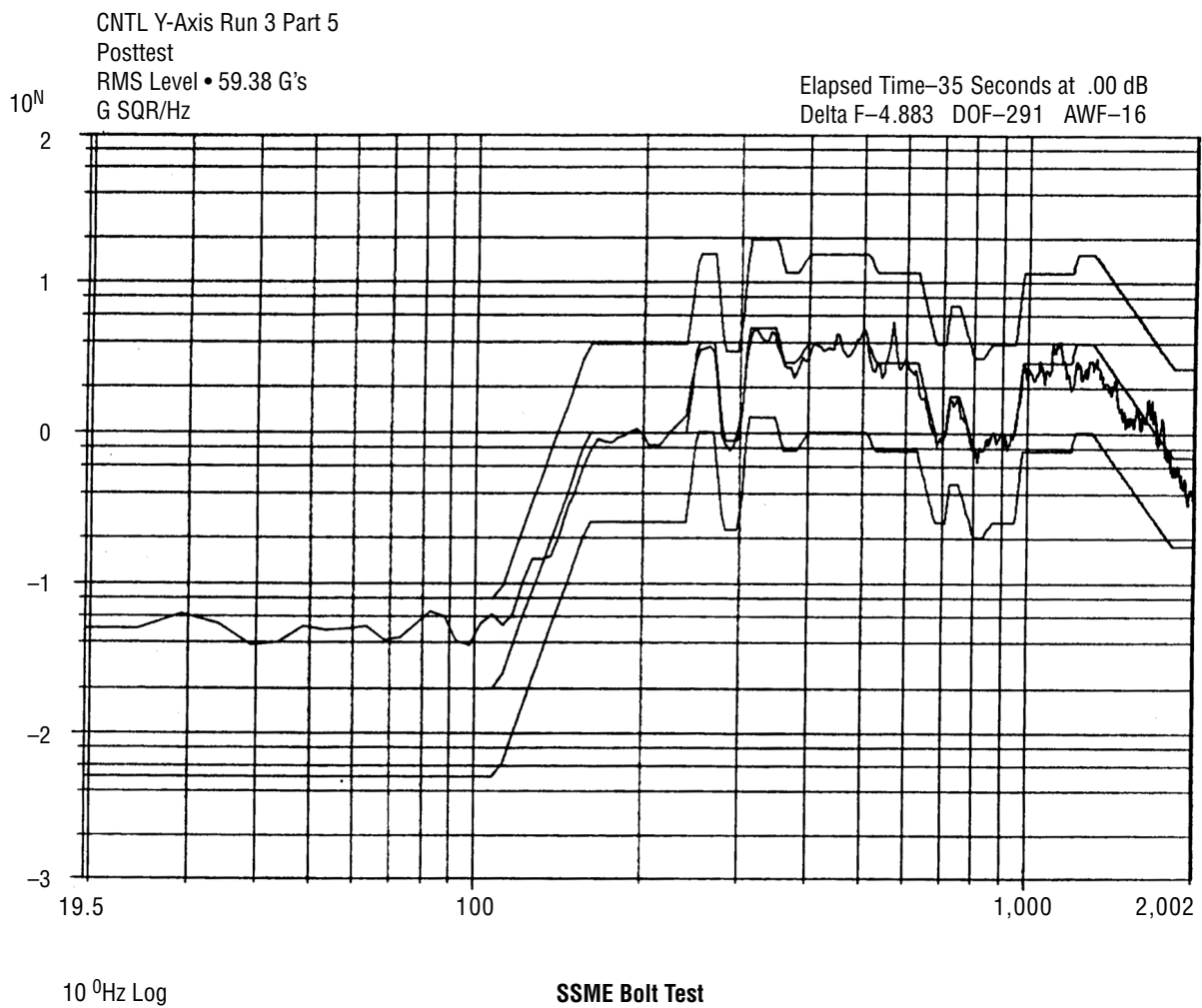


FIGURE D-6.—Run 3, part 3, at 35 seconds.

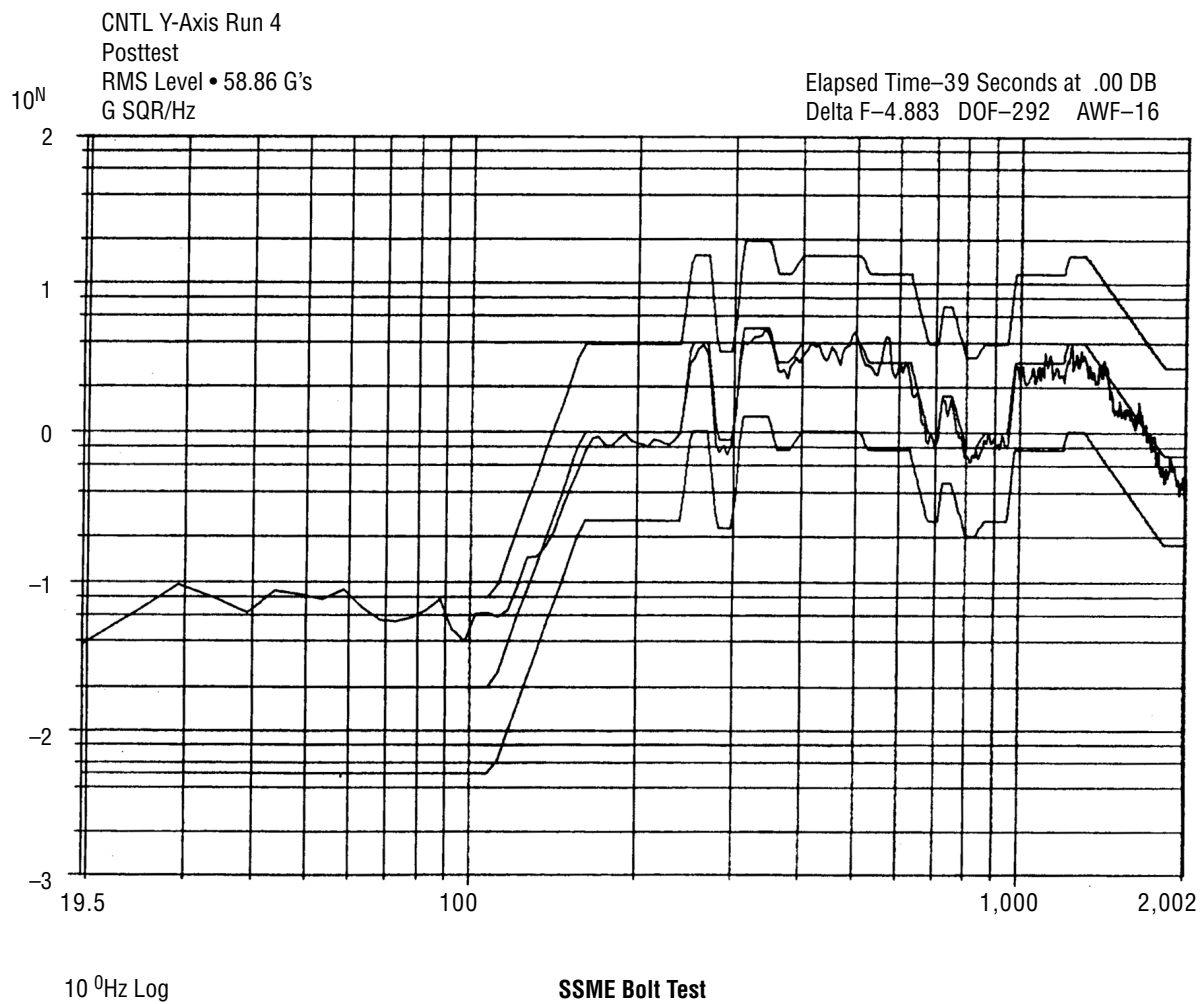
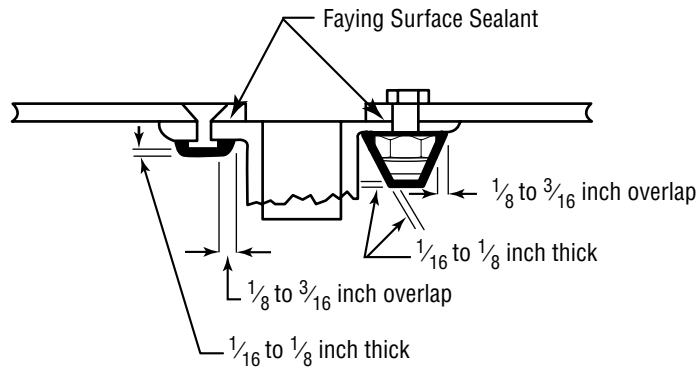
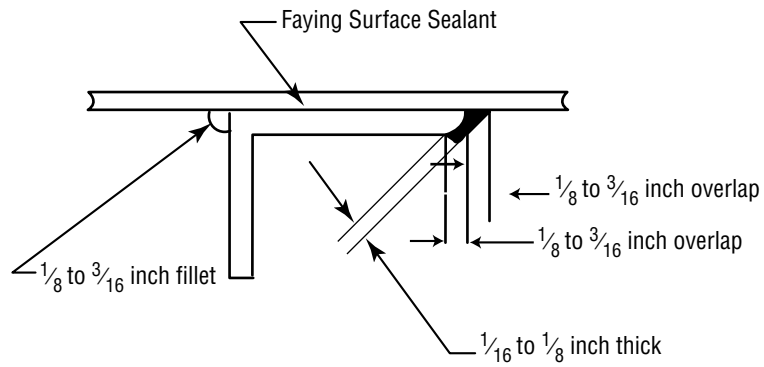
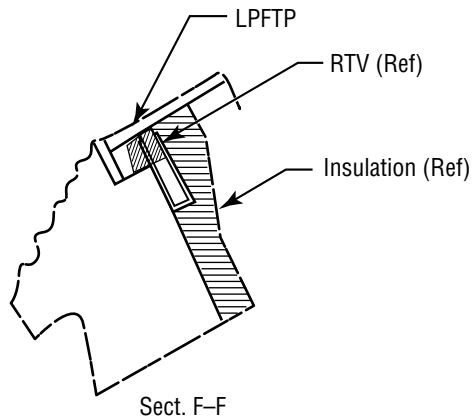


FIGURE D-7.—Run 4, at 39 seconds.

APPENDIX E— RTV APPLICATION DESCRIPTION



Source: Rockwell Space Division document MA0106-303.



Source: Rockwell Space Division drawing V070-410801.

APPENDIX F— TORQUE TEST DATA

TYPE <input type="checkbox"/> A CONFIGURATION CHANGE <input type="checkbox"/> B NON CONFIGURATION CHANGE		TEST PREPARATION SHEET PRINTED ON 02/07/97 @ 1:10 PM		TPS NUMBER WTA-0024-M <hr/> S/C CAT NUMBER CW7816																																											
MOD SHEET NUMBER _____				PAGE 1 OF 1																																											
TPS SHORT TITLE Perform Break and Run on Various Bolts				SAFETY HAZARD <input type="checkbox"/> YES <input type="checkbox"/> NO LIMITED LIFE EQUIP. <input type="checkbox"/> YES <input type="checkbox"/> NO																																											
FACILITY WTA		DATE 02/07/97		NEED DATE 02/07/97																																											
DRAWING(S), DOCUMENTS, TCP(S) & PART NO(S)				MATERIAL ENGINEER SIGNATURE <input type="checkbox"/> YES <input type="checkbox"/> NO																																											
INITIATING ORGANIZATIONS WTA		SYSTEM MECHANICAL		CONSTRAINT NONE																																											
REASON FOR WORK Required by SSME office for information only.				PROJECT NUMBER(S) P1999																																											
NO.	DESCRIPTION			TECH	INSPECTOR CONT NASA																																										
1.	Perform break and run on various bolts as requested by Ron Tepool. Record information only. <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="text-align: center;">Bolt size</td> <td style="text-align: center;">Break</td> <td style="text-align: center;">Run</td> <td style="text-align: center;">Cable</td> <td style="text-align: center;">RTV</td> <td style="text-align: center;">Foam</td> </tr> <tr> <td style="text-align: center;">[#1 0.375]</td> <td style="text-align: center;">[6.5 lb/in]</td> <td style="text-align: center;">[3 lb/in]</td> <td></td> <td style="text-align: center;">x</td> <td style="text-align: center;">x</td> </tr> <tr> <td style="text-align: center;">[#2 0.375]</td> <td style="text-align: center;">[7 lb/in]</td> <td style="text-align: center;">[2 lb/in]</td> <td style="text-align: center;">x</td> <td style="text-align: center;">x</td> <td style="text-align: center;">x</td> </tr> <tr> <td style="text-align: center;">[#3 0.3125]</td> <td style="text-align: center;">[4 lb/in]</td> <td style="text-align: center;">[1.5 lb/in]</td> <td></td> <td style="text-align: center;">x</td> <td style="text-align: center;">x</td> </tr> <tr> <td style="text-align: center;">[#4 0.3125]</td> <td style="text-align: center;">[3.5 lb/in]</td> <td style="text-align: center;">[2 lb/in]</td> <td></td> <td style="text-align: center;">x</td> <td style="text-align: center;">x</td> </tr> <tr> <td style="text-align: center;">[#5 0.250]</td> <td style="text-align: center;">[3.5 lb/in]</td> <td style="text-align: center;">[1.5 lb/in]</td> <td style="text-align: center;">x</td> <td style="text-align: center;">x</td> <td style="text-align: center;">x</td> </tr> <tr> <td style="text-align: center;">[#6 0.250]</td> <td style="text-align: center;">[2 lb/in]</td> <td style="text-align: center;">[1.5 lb/in]</td> <td></td> <td></td> <td></td> </tr> </table> TW CCN <u>M26844</u> D/D <u>2/15/97</u> .			Bolt size	Break	Run	Cable	RTV	Foam	[#1 0.375]	[6.5 lb/in]	[3 lb/in]		x	x	[#2 0.375]	[7 lb/in]	[2 lb/in]	x	x	x	[#3 0.3125]	[4 lb/in]	[1.5 lb/in]		x	x	[#4 0.3125]	[3.5 lb/in]	[2 lb/in]		x	x	[#5 0.250]	[3.5 lb/in]	[1.5 lb/in]	x	x	x	[#6 0.250]	[2 lb/in]	[1.5 lb/in]					
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2.	Close this TPS. TPS was annotated by V. Yost based on interviews with R. Tepool.																																														
SPECIAL NOTES					QE CLOSE																																										
PREPARED BY LIGHTFOOT, ROBERT			PHONE 4-4035	FINAL ACCEPTANCE	DATE																																										
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LIGHTFOOT, ROBERT			02/07/97	RONALD W. JOHNSON, JR.																																											

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6. AUTHORS V.H. Yost				
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13. ABSTRACT (Maximum 200 words) During a walkdown of the Space Transportation System (STS) orbiter for the 82nd Space Shuttle flight (STS-82), technicians found several safety cables for bolts with missing or loose ferrules. Typically, two or three bolts are secured with a cable which passes through one of the holes in the head of each bolt and a ferrule is crimped on each end of the cable to prevent it from coming out of the holes. The purpose of the cable is to prevent bolts from rotating should they become untightened. Other bolts are secured with either a locking cable or wire which is covered with RTV and foam. The RTV and foam would have to be removed to inspect for missing or loose ferrules. To determine whether this was necessary, vibration and torque test fixtures and tests were made to determine whether or not bolts with missing or loose ferrules would loosen. These tests showed they would not, and the RTV and foam was not removed.				
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